Phosphoric Acid Fuel Cells

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Fuel Cell Workshop
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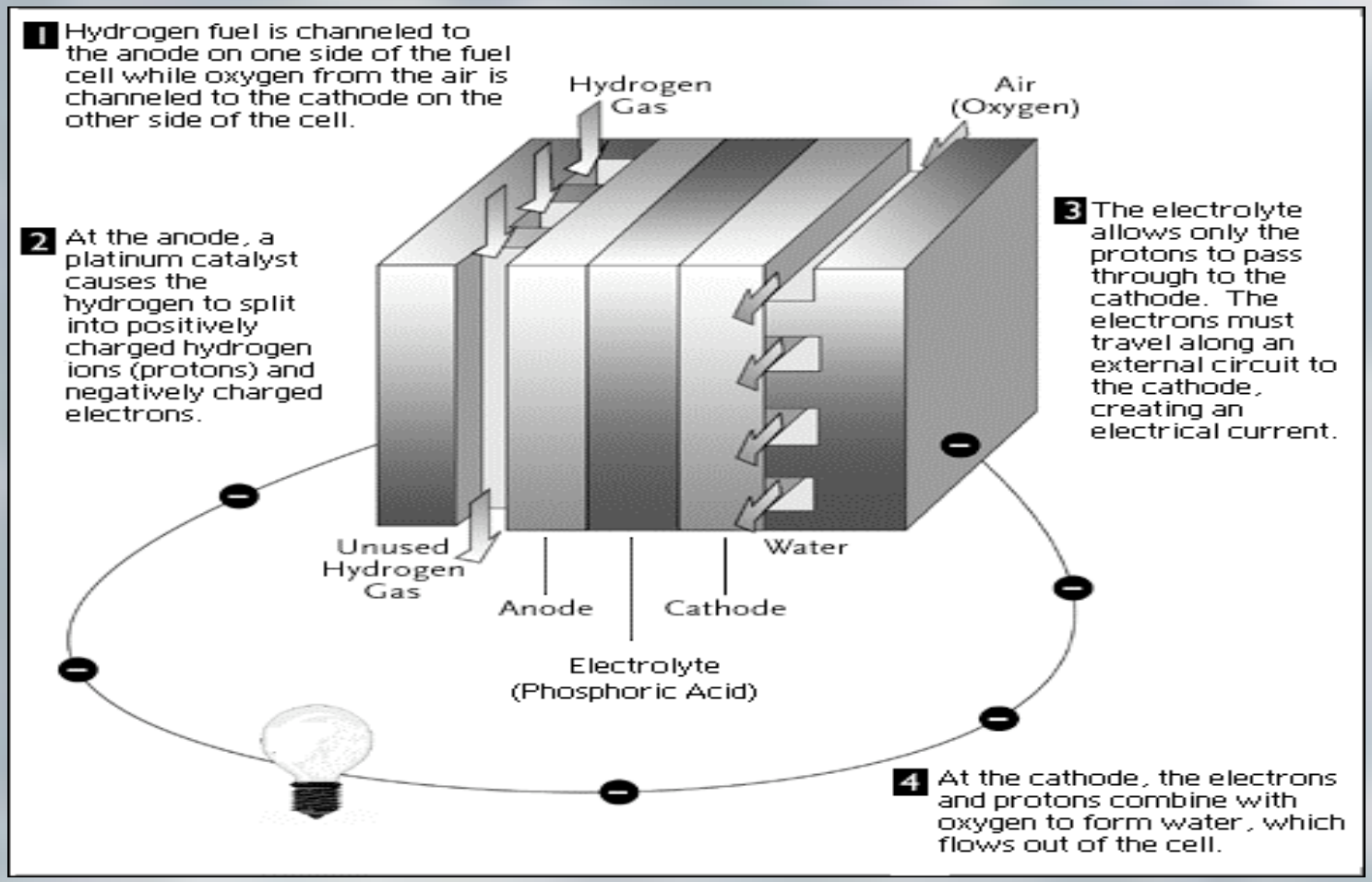
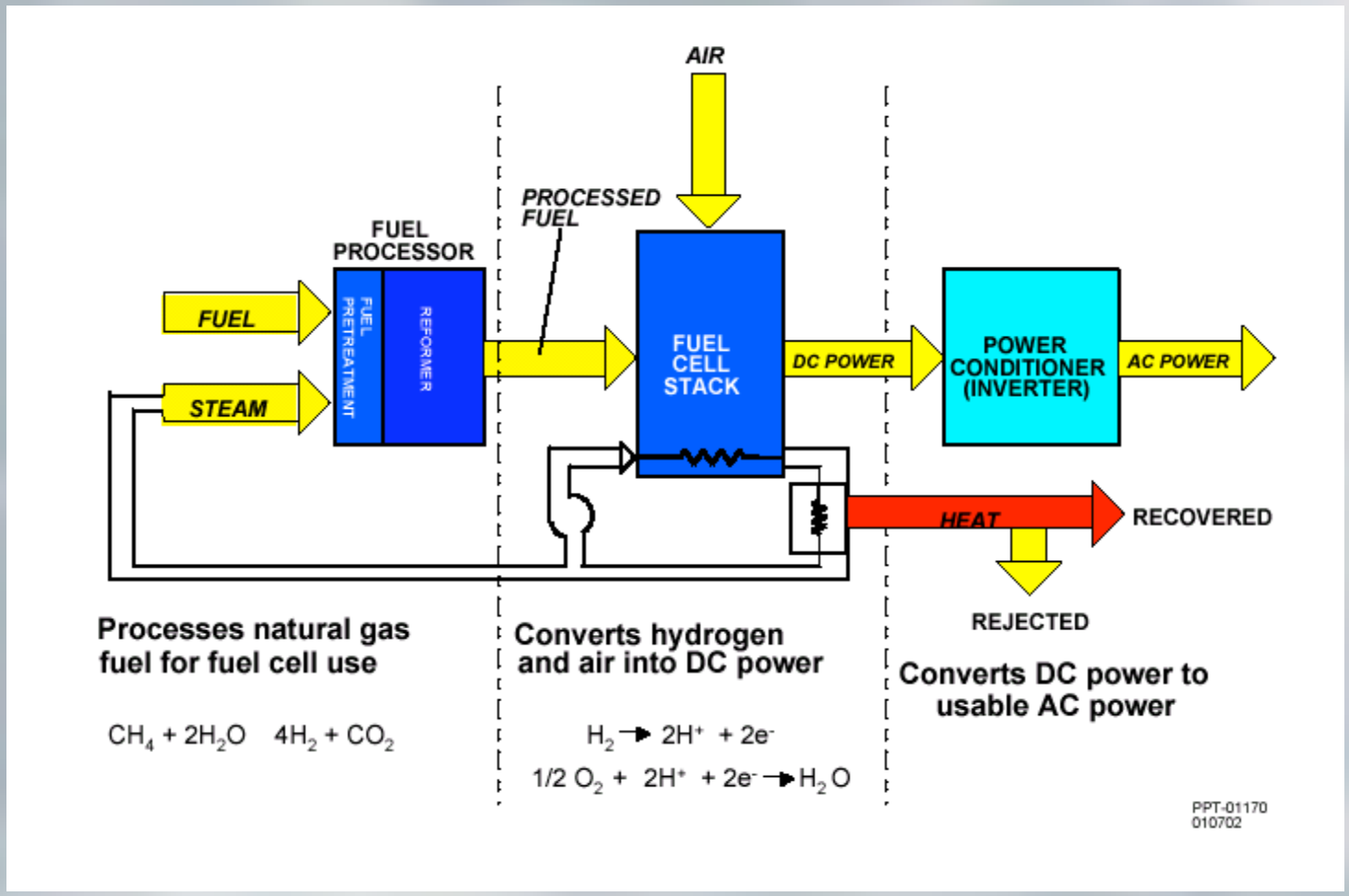
PAFCs– How They Work



Balance of Plant (BOP)



U. S. PAFC Companies

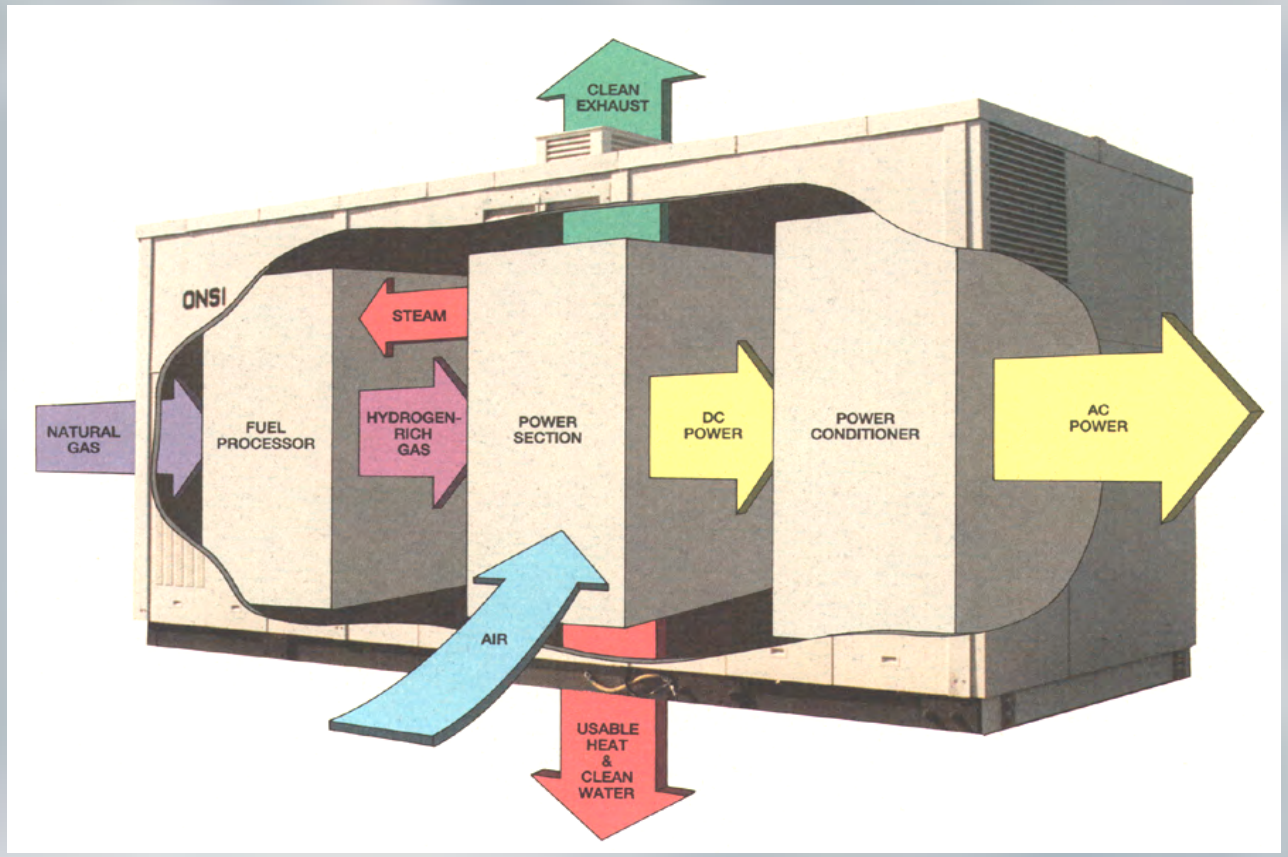
- United Technologies Corporation (UTC)
- HydroGen LLC

UTC Fuel Cells

PureCell™ 200 Power Solution

PureCell™ 200

(Previously PC25™)



PureCell™ 200

- Commercialized in 1992
- 200 kW AC Power Out (Computer Grade)
  - Grid-Connect
  - Grid-Independent
  - Grid-Connect/Grid-Independent
- 925 kBtu/hr Heat Output
  - 140°F
  - 140/250°F
- Natural Gas or ADG

PureCell™ 200

- Electrical Efficiency ~ 40% (LHV)
- Overall Efficiency (Elect + Thermal) ~85%
- Availability > 96%
- Ultra Low Air Emissions
  - Exempt From Air Emission Permitting in SCAQMD (Amendment 209)
  - Meets or Exceeds All CARB07 Air Emission Standards

PureCell™ 200

- Stack Life Warranty – 40,000 hours
- Cost - $850,000 ($4,200/kW)
- > 275 Units Installed To Date
  - 19 Countries
  - 5 Continents
- > 1.1 billion kWh Generated To Date
- > 7 million Total Hours of Fleet Operation To Date

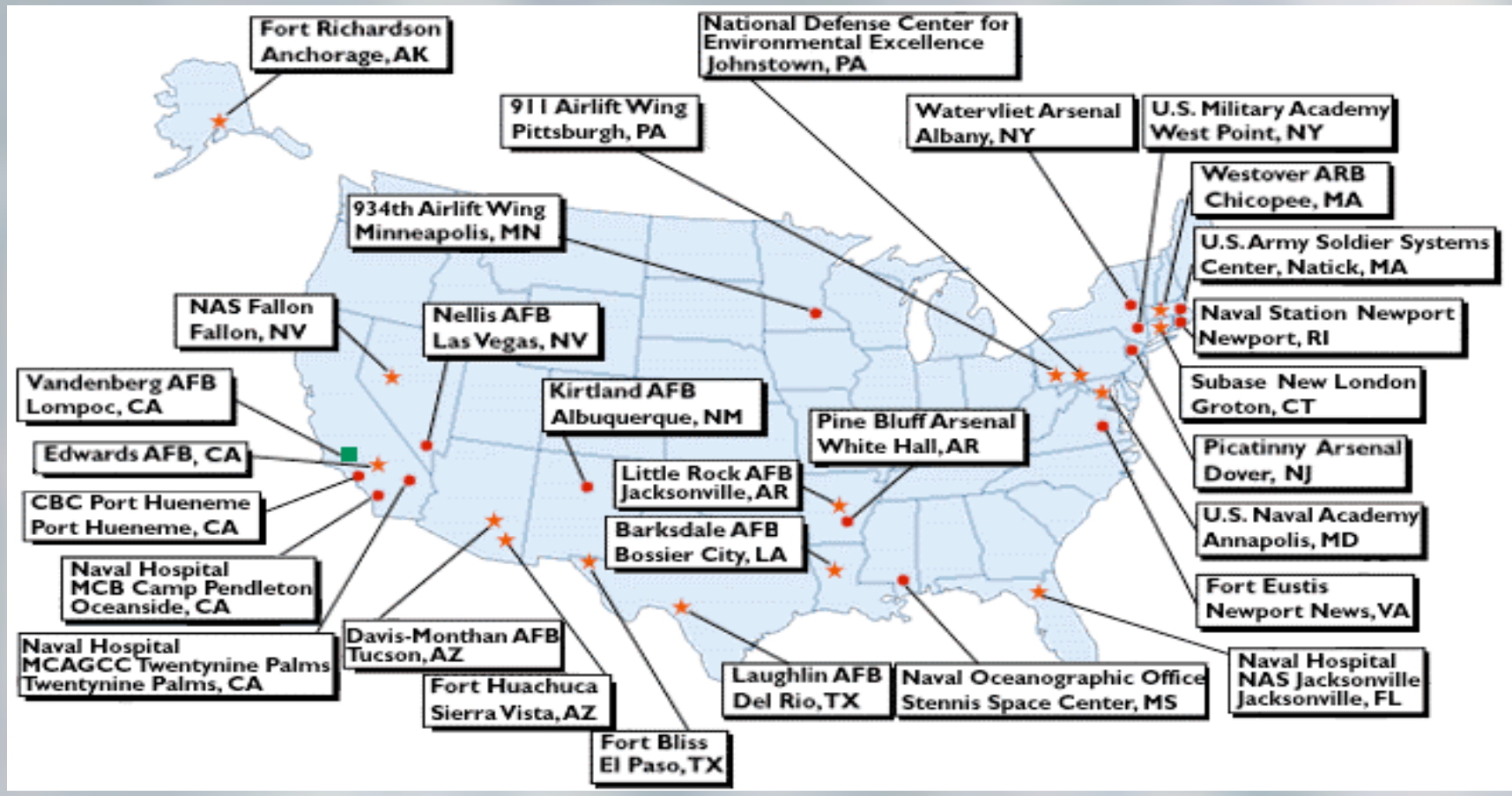
DoD PAFC Demonstration Program

- DUECC Request for CERL Assistance
- FY93 Congressional Appropriation - $18M
- FY94 Congressional Appropriation - $18.75M
- Specify “...natural gas fuel cells in production in the United States...”

Turn-key Package

- IFC PC25 Fuel Cell Power Plant
  - Fy93 - 1 ea. Model A, 11 ea. Model B
  - Fy94 - 3 ea. Model B, 15 ea. Model C
- Engineering Design / Installation
- Training for Site Personnel
- 60 Months Maintenance
- Diagnostic / Remote Monitoring Computer

DoD PAFC Program Sites



DoD Facility Applications

- **Central Heat Plants**
  - **11 Sites**
- **Hospital Utility Plants**
  - **7 Sites**
- **Pool / Gymnasiums**
  - **3 Sites**
- **Others**
  - **Barracks, Dining Facility, Laundry, NG Armory, Launch Control Bldg., Office, Evaporator process**

FY93 Program Sites

934th Airlift Wing, Minneapolis MN

Kirtland AFB, Albuquerque NM

Nellis AFB, Las Vegas NV

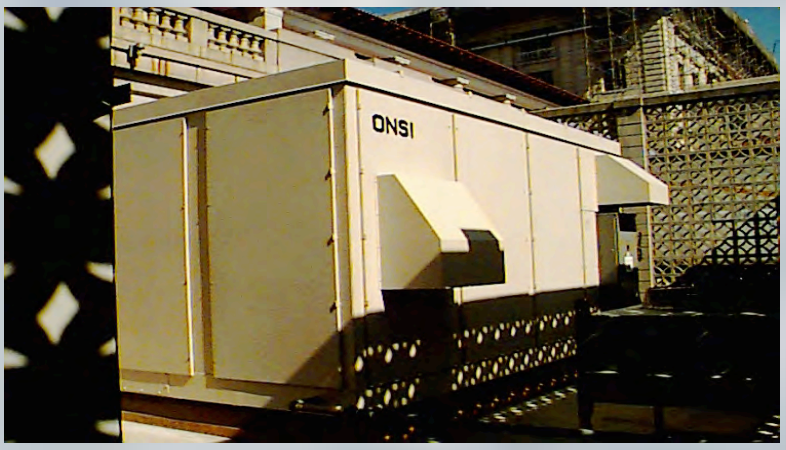
Vandenberg AFB, Lompoc CA

FY93 Program Sites

Naval Hospital, MCAGCC 29 Palms, 29 Palms CA

Naval Hospital, MCB Camp Pendleton, Oceanside CA

Naval Education Training Center, Newport RI



US Naval Academy, Annapolis MD

FY93 Program Sites

U.S. Army Soldier Systems Command, Natick MA

Ft. Eustis, Newport News VA

Picatinny Arsenal, Dover NJ

U.S. Military Academy, West Point NY

FY94 Program Sites

911th Airlift Wing, Pittsburgh PA

NAS Fallon, Fallon NV

Ft. Richardson, Anchorage AK

Naval Hospital, NAS Jacksonville, Jacksonville FL

FY94 Program Sites

Edwards AFB, CA

Barksdale AFB, Bossier City LA

Ft. Huachuca, Sierra Vista AZ

National Defense Center for Environmental Excellence (NDCEE), Johnstown PA

FY94 Program Sites

CBC Port Hueneme, Port Hueneme CA

Laughlin AFB, Del Rio TX

Naval Oceanographic Office
John C. Stennis Space Center, MS

Westover ARB, Chicopee MA

FY94 Program Sites

Ft. Bliss, El Paso TX

Subase New London, Groton CT

Little Rock AFB, Jacksonville AR

Pine Bluff Arsenal, White Hall AR

FY94 Program Sites

Watervliet Arsenal, Albany NY

Davis-Monthan AFB, Tucson AZ

LOGANEnergy Project

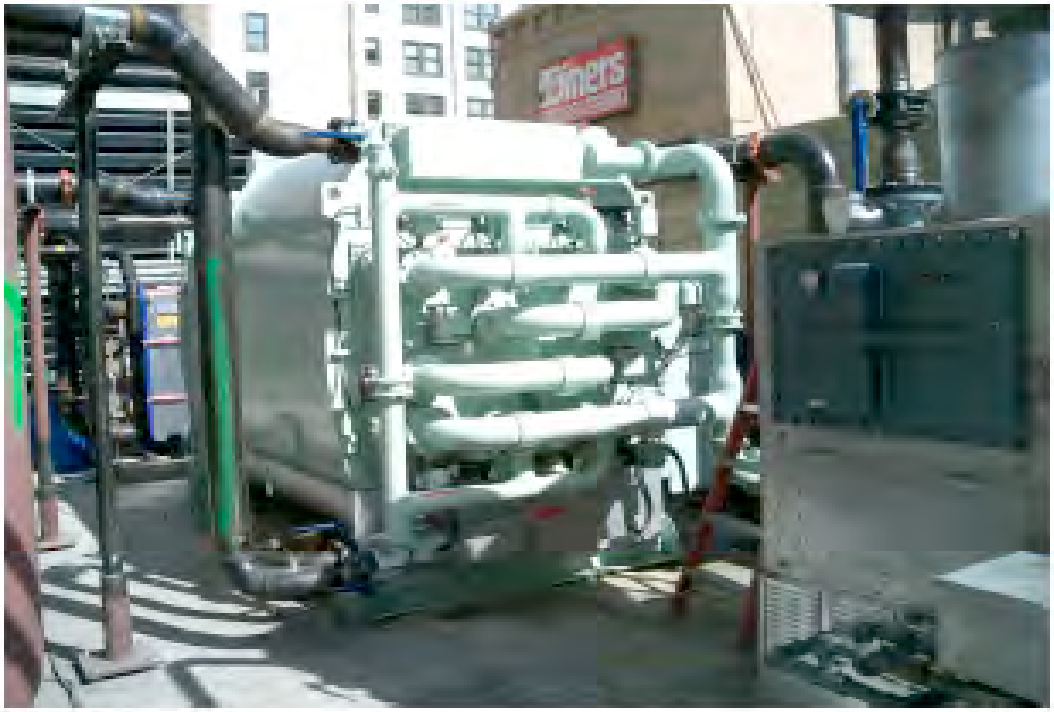
LOGANEnergy

600kWe Fresno, California Project
100 ton Adsorption Air-Conditioning

Market Leader

Proven Success

Profitable Company



UTC - Future Developments

- 2007: Stack Life Warranty – 80,000 Hours
- 2009: PureCell™ 400
- 2007-2009: Price Decrease To ~$2,000 - $2,500/kW

HydroGen LLC

HydroGen LLC - Overview

- Technology is a 400kW air-cooled PAFC cell generator
- Technology was developed by Westinghouse in a cost-shared R&D program with the Department of Energy
- Technology was designed for industrial, utility, and multi-MW premium power applications
- All technology goals met or exceeded from R&D program – millions of hours of successful testing in-house

HydroGen LLC - Overview

- Technology is ready for commercial-scale demonstration, and incorporation into a standardized product platform

- Company's standard product platform is a 2MW 'power island'
  - Five 400kW modules → 2MW
  - HydroGen builds power plants in the 6-30MW range → 3-15 power standard power islands of 2MW

Features of the HydroGen Air-cooled PAFC Module

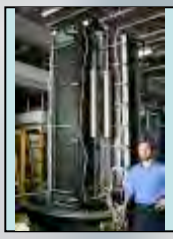
- Capacity: 400kW
- Size: 11’ tall, 7’ diameter
- Efficiency: 43% (LHV – available H2)
- Cogen: Up to 70psia steam @ 360°F
- Net water: Up to 160 gal/hour for 2MW system
- Air-cooling: Simple assembly, reduced corrosion
- PA addition: During stack operation - patented

2MW Power Island

Terminology – from fuel cell to fuel cell power plant

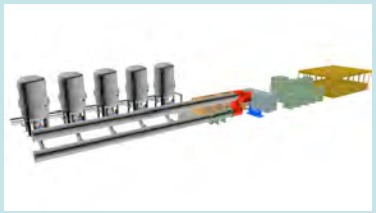

Pilot manufacturing

Air-cooled fuel cells stacked

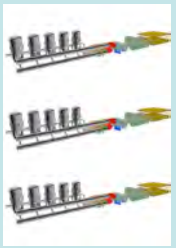


4 stacks of 100kW each

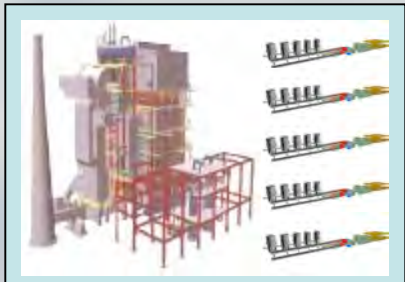
400 kW module



2 MW Power Island

6 MW Power Plant – H2 available



10 MW Power plant – with H2 plant

Cost Reduction: THE issue

Fuel cell system cost depends on:

- ***Simplicity*** of fuel cell stack technology and Balance of Plant (BOP)
- ***Fuel processing*** method
- ***Size*** of system

HydroGen technical philosophy and product strategy:

- ***Simple***, robust Westinghouse fuel cell module technology and standard BOP
- ***Un-bundle*** the fuel processing, and use H_2 infrastructure or mature hydrogen plant technology
- ***Large systems*** → 6-30MW
- ***Current Cost*** - \$3,000/kW (1st 6-MW Plant)/\$1,500/kW (1st 25-MW Plant) – Hydrogen-Fueled

What Next???

- PAFC Technology Is Quite Mature
- PAFC Manufacturers Are Funding In-House R&D To Reduce Costs Further Through Technology Advancements
- Cost Reduction Through Economies of Scale Are Required To Achieve Large-Scale Market Penetration
- Target Market Price: <$1,500/kW
- Incentive Programs Are Very Helpful for PAFC Technology

California Can Be An Early Adopter of PAFC Technology

California is different from much of the rest of the country with respect to:

- Rapid population growth, especially in the Central Valley
- Reliance on natural gas for electricity generation. Coal-based supply is located out of state
- Air quality non-attainment

One Idea - HyCoGen

- Joint Effort of U.S. Army ERDC-CERL, FC*Tec*, and LOGANEnergy
- Allows PureCell 200 Fuel Cell To Tri-generate – Electricity, Heat, and Hydrogen
- Hydrogen is Taken Off the Reformer When Needed to Fill Storage Tanks (Electricity and Heat Output are Temporarily Reduced)

HyCoGen – A Smart Approach To Building the Hydrogen Highway

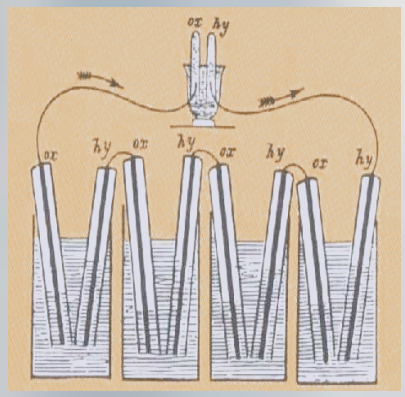
- Typical Hydrogen Fueling Stations Sit Idle Most of the Time Due to the Highly Limited Number of Hydrogen Vehicles Today
- When HyCoGen Is Not Needed To Generate Hydrogen For Storage For Vehicle Fueling, It Generates 200 kW Electricity and 925 kBtu/hr of Useful Heat
- Water Treatment Plants Make Ideal Locations Due To the “Free” ADG Fuel

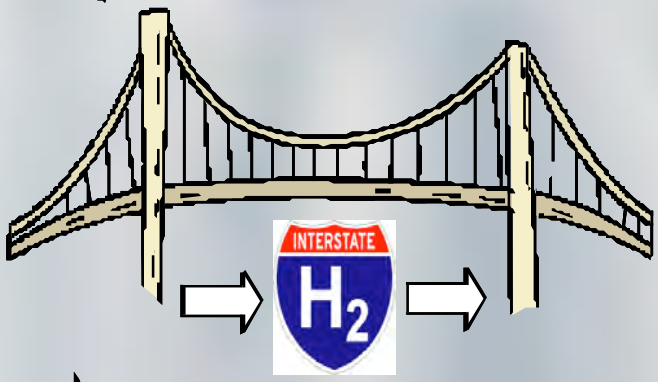
MBA

Mike Binder and Associates, Inc.

Fuel Cell Consulting Services

Bridging the Gap





From Dream to Reality

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